50 Years Ago

Goffman and Newill have directed attention to the analogy between the spreading of an infectious disease and the dissemination of information. We have recently examined the spreading of a rumour from the point of view of mathematical epidemiology … a mathematical model for the spreading of rumours can be constructed in a number of different ways … 'Reluctance to tell stale news' can be incorporated into the model.

From *Nature* 12 December 1964

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100 Years Ago

In Nature of December 3…there appeared a brief abstract of a paper communicated by Mr. Reginald A. Smith…on behalf of its author, Major E. R. Collins, D.S.O., now a wounded prisoner of war in Germany. This paper is not only an important contribution to our knowledge of the prehistoric stone implements of South Africa, but is evidence that a brave and capable soldier may, while helping to shape the history of his own time, give material assistance in unravelling the past history of the country through which he may be campaigning. Major Collins collected the material for his paper while engaged on trenching operations during the late Boer war … Major Collins made his collection of the stone industries of the ancient inhabitants of South Africa, keeping systematic records of the deposits in which the various implements occurred … I have little doubt that some of our French colleagues, amidst all the dangers and anxieties which attend the present war, will avail themselves of the opportunities presented by the extensive trenching operations in northern France to extend further our knowledge of prehistoric times.

From *Nature* 10 December 1914

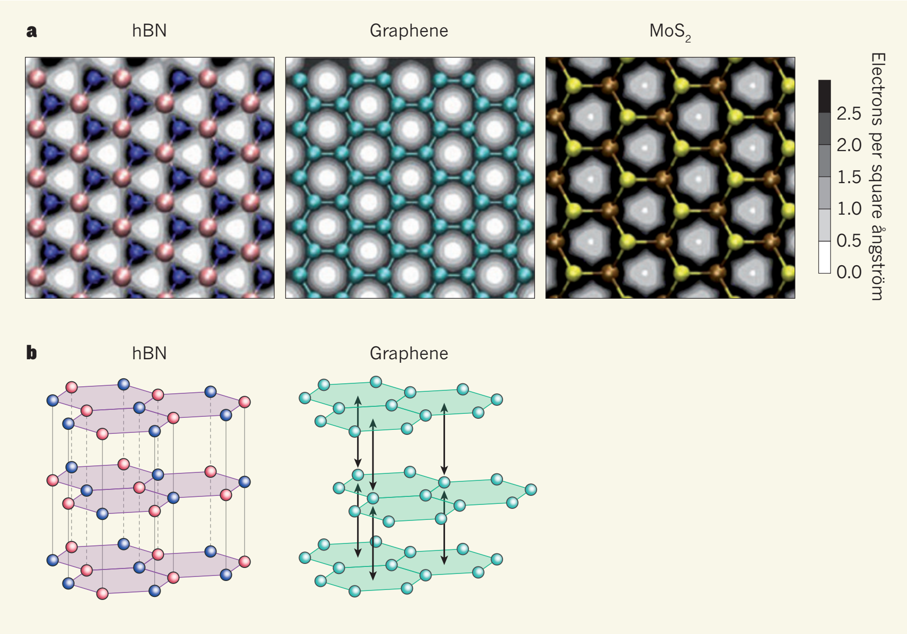

Figure 1 | Electron density distribution in two-dimensional materials. **a**, The densities of the electron clouds around hexagonal boron nitride (hBN), graphene and molybdenum disulphide (MoS_2) reveal successively lower 'porosities'. These porosities correspond to the ability of the materials to conduct protons[2]: hBN conducts better than graphene, whereas MoS_2 does not conduct. Nitrogen atoms, dark blue; boron, pink; carbon, light blue; molybdenum, brown; sulphur, yellow. **b**, The lattice structure of multi-layered hBN is aligned (as are its 'pores'), whereas that of multi-layered graphene is staggered so that its pores are not above each other; double-headed arrows indicate atoms sandwiched between pores. This explains why bi- and trilayers of hBN conduct protons, but bilayers of graphene do not.

two-dimensional materials. In monolayers, the electron clouds of hBN are more 'porous' than those of graphene (Fig. 1). MoS_2 does not have any 'pores' in its electron cloud, and so does not conduct protons. In multilayered hBN, the pores of successive layers align with each other, allowing protons to pass. By contrast, the lattice in multi-layered graphene is staggered such that the electron cloud of one layer blocks the pores in the next layer.

The proton conductivity of both graphene and hBN exhibited Arrhenius-type exponential increases with temperature, but graphene showed a faster rate of increase than hBN. Such temperature-dependent behaviour indicates that proton transport involves passage across an energy barrier, rather than some other mechanism. Hu and co-workers also showed that the proton conductivity could be enhanced more than tenfold by simply coating the two-dimensional materials with a discontinuous layer of platinum, a widely used catalyst often found in fuel cells.

Proton-conductive membranes are at the heart of proton-exchange membrane fuel cells, in which the 'proton exchange' membrane must conduct protons while preventing crossover of water and methanol[3]. Considerable efforts have been directed towards developing moisture-free membranes that can operate at high temperatures (greater than 120 °C) to resolve several technical problems and improve fuel-cell performance, but no membrane has completely succeeded in replacing conventional, low-temperature hydrated membranes[3]. Could graphene or hBN — which exhibit high proton conductivity but are otherwise impenetrable — provide the long-sought solution? Graphene monolayers are stable in oxygen up to 400 °C (ref. 4), whereas hBN is even more stable (its nanotube form survives temperatures of 700 °C in air[5]). And in Hu and colleagues' experiments, platinum-coated hBN was so conductive that it was essentially 'invisible' to protons. In all likelihood, the proton conductivities of pristine graphene and platinum-coated hBN exceed 50 siemens per square centimetre at high temperatures — this is the target[6] set by the US Department of Energy for the conductance of proton-exchange membranes to be developed by the year 2020. However, it may be difficult to create the large membranes of pristine graphene or hBN needed for fuel-cell applications. One practical solution could be to make a composite membrane of graphene or hBN flakes and a platinum catalyst, along the lines of another fuel-cell membrane made from flakes of graphene oxide that was reported this year[7].

The electrical properties of graphene and hBN are diametrically opposed — which, in the context of Hu and co-workers' findings, means that graphene is an electrically conductive proton conductor, whereas hBN is an electrically insulating proton conductor. The insulating characteristics of hBN raise the intriguing possibility of creating ultrathin